

**DISC DRIVE APPARATUS HAVING DRIVE**  
**ELECTRONICS TOP MOUNTED ON FLEXIBLE**  
**PRINTED CIRCUIT BOARD**

by

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**DISC DRIVE APPARATUS HAVING DRIVE ELECTRONICS TOP  
MOUNTED ON FLEXIBLE PRINTED CIRCUIT BOARD**

**Related Applications**

5           This application claims priority of United States provisional application  
Serial Number 60/404,682, filed August 20, 2002.

**Field of the Invention**

          This application relates generally to data storage devices and more  
particularly to the placement of electronic control circuit components in a data  
10   storage device.

**Background of the Invention**

          Disc drives are data storage devices that store digital data in optical, opto-  
magnetic, and/or magnetic form on a rotating storage medium on a disc. The  
typical disc drive includes a base plate on which various structural components are  
15   mounted. The various structural components include, for example, a disc, an  
actuator assembly, and a spindle motor rotating the disc. Modern magnetic disc  
drives comprise one or more rigid discs that are coated with a magnetic medium  
and mounted on a hub of the spindle motor for rotation at a constant high speed.  
Information is stored on the discs in a plurality of concentric circular tracks  
20   typically via an array of transducers mounted to a rotary actuator for movement of  
the heads relative to the discs. The disc drive motor assembly, collectively known  
as a head/disc assembly (HDA), a device having all control electronic circuits  
integrated above the base plate, and the actuator are typically enclosed on the base  
plate by a cover forming a sealed environment to prevent contamination within the  
25   system that could result in disc failure.

          The typical disc drive also includes a printed circuit board assembly that  
provides the majority of the electronic circuits necessary for control of operation of  
the disc drive, including controlling positioning of the actuator and transducers.  
This printed circuit board assembly is mounted outside the sealed head disc  
30   assembly traditionally, beneath the disc drive plate on an underside surface of the  
base. Input and output signals are fed to and from the disc drive via the printed

circuit board circuitry and the HDA. These signals are typically supplied to the HDA via a pass-through connector that extends through and seals an opening into the enclosed head disc assembly and then through a flexible printed circuit cable to the actuator assembly. The printed circuit cable has one end physically terminating  
5 on the actuator assembly and the other end connected to the pass-through connector. These terminations inherently exhibit losses.

One problem that has arisen with this design is that it necessitates several connections between the components on the printed circuit board and the flex-circuit cable, which increases the losses in the electrical circuitry system.  
10 Accordingly there is a need for a disc drive system that reduces or eliminates these problems. The present invention provides a solution to this and other problems, and offers other advantages over the prior art.

In addition, the printed circuit board, the pass-through connector and flex-circuit cable are traditionally attached to the base plate and then physically  
15 electrically connected to each other in separate steps. Because the manufacturing process currently requires these separate steps, it is also desirable to provide a system that eliminates some of these steps.

### **Summary of the Invention**

20 Against this backdrop embodiments of the present invention have been developed. One embodiment of the invention features a disc drive having all of its actuator servo-controls and signal processing electronics circuitry incorporated onto a flexible printed circuit assembly positioned on a top surface of the base plate adjacent the external power and interface connector of the disc and alongside the  
25 head disc assembly (HDA), which includes the actuator assembly and the discs mounted on the spindle motor enclosed between the base plate and cover. In this embodiment, the top cover together with the base plate encloses only the HDA. The cover avoids the power, actuator servo-controls and signal processing electronics components mounted on the flexible printed circuit board adjacent the  
30 HDA so that these components may be cooled by ambient air circulation.

In another aspect of the invention, the flexible printed circuit board is attached to a stiffener plate against a bottom surface of the flex printed circuit

board. This stiffener plate functions in a multiplexing fashion as an electrical ground plane and a power plane for the components mounted on the flex printed circuit assembly. The printed circuit assembly and power and ground plane stiffeners are electrically connected to the components by a network of metal stakes. The flexible printed circuit board and stiffener plate assembly is inserted into and connected to the external power and interface connector that is, in turn, fastened to the base plate of the disc drive.

The flexible circuit board assembly of the invention includes a pigtail lead trace that extends beneath the discs in the HDA to provide power to the spindle motor. The flexible circuit board also includes a lead trace that connects to the actuator assembly within the HDA.

In an alternative embodiment the flexible circuit board assembly includes an actuator lead pad to which a separate lead trace, fastened to the actuator assembly during HDA assembly, is connected.

These and various other features as well as advantages which characterize the present invention will be apparent from a reading of the following detailed description and a review of the associated drawings.

#### **Brief Description of the Drawings**

FIG. 1 is a plan view of a disc drive incorporating one embodiment of the present invention showing the primary internal components of the disc drive beneath the cover in dashed lines.

FIG. 2 is a separate exploded perspective view of a flexible printed circuit assembly of the embodiment shown in FIG. 1.

FIG. 3 is a separate plan view of the flexible printed circuit assembly shown in Figure 2.

FIG. 4 is a perspective view of the disc drive in Fig. 1 with the cover spaced from the head disc assembly.

FIG. 5 is a plan view of a disc drive in accordance with an alternative embodiment of the present invention as in FIG. 1 with the top cover in place.

FIG. 6 is a separate plan view of the alternative flexible printed circuit assembly and connector in the embodiment shown in Figure 5.

FIG. 7 is a perspective view of the disc drive in accordance with the alternative embodiment of the present invention shown in FIG. 5 with the top cover spaced from the head disc assembly.

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### **Detailed Description**

A disc drive **100** constructed in accordance with an embodiment of the present invention is shown in FIG. 1. Throughout this specification like numerals will be used to identify like elements in the various embodiments shown and described for consistency and ease of identification. The disc drive **100** includes a  
10 base plate **102** to which various components of the disc drive **100** are mounted. This base plate is essentially a generally rectangular plate that has a peripheral wall to which a top cover **104** is attached. The top cover **104** cooperates with the base plate **102** to form an internal, closed head disc assembly (HDA) environment for several of the various components of the disc drive. These components are shown  
15 in dashed lines in FIG. 1. The components include a spindle motor **106** that rotates one or more data storage discs **108** at a constant high speed. Each of these data storage discs supports on its surface a storage media such as optical media or a layer of magnet media. Information is written to and read from tracks on the discs **108** through the use of an actuator assembly **110**, which rotates during a seek  
20 operation about a bearing shaft assembly **112** positioned adjacent the discs **108**. The actuator assembly **110** includes a plurality of actuator arms **114** which extend towards the discs **108**, with one or more flexures **116** extending from each of the actuator arms **114**. Mounted at the distal end of each of the flexures **116** is a head **118** that includes a fluid bearing slider enabling the head **118** to fly in close  
25 proximity above the corresponding surface of the associated disc **108**.

During a seek operation, the track position of the heads **118** is controlled through the use of a voice coil motor (VCM) **124**, which typically includes a coil **126** attached to the actuator assembly **110**, as well as one or more permanent magnets (not shown) which establish a magnetic field in which the coil **126** is  
30 immersed. The controlled application of current to the coil **126** causes magnetic interaction between the permanent magnets and the coil **126** so that the coil **126** moves in accordance with the well known Lorentz relationship. As the coil **126**

moves, the actuator assembly **110** pivots about the bearing shaft assembly **112**, and the heads **118** are caused to move across the surfaces of the discs **108**.

A flex printed circuit board assembly **130**, in accordance with an embodiment of the invention, provides the requisite electrical connection paths to and from the actuator assembly **110** while allowing pivotal movement of the actuator assembly **110** during operation, supports power and control electronics components for the spindle motor **106** and control of the actuator assembly **110**, lead traces to a preamplifier mounted on the actuator assembly **110** and lead traces connected to the motor **106**. The head wires (not shown) are routed from the preamplifier **165** along the actuator arms **114** and the flexures **116** to the heads **118**.

The flex printed circuit board assembly **130** in the embodiment shown in FIG. **1** is separately shown in FIGS. **2** and **3** and a perspective view of the installation of the flex assembly **130** is shown in FIG. **4**. The flex assembly **130** preferably includes circuitry for controlling the write currents applied to the heads **118** during a write operation and a preamplifier **165** for amplifying read signals generated by the heads **118** during a read operation. As is shown in FIG. **2**, the flex assembly **130** has a flexible printed circuit **131** and a stiffener plate **140** fastened to the flexible printed circuit **131**. The stiffener plate **140** and circuit **131** are in turn inserted into a slot in the rear of the connector **150** to electrically connect the traces on the circuit **131** to the connector pins of the connector **150**. The connection between these pins and the traces (not shown) may be compression fit, soldered in place in a conventional manner, or otherwise electrically and physically connected to complete the flex assembly **130**.

The flex assembly **130** preferably includes a multi-chip packaged (MCP) component **132** (also called a multi-chip module), passive components **133** such as discrete resistors, capacitors and diodes, and a power combo chip **134** soldered, or otherwise physically fastened, directly onto the flexible circuit **131** of the flex assembly **130**. MCP's are modules that have multiple integrated circuits packaged on an insulating substrate. The integrated circuits are interconnected on the MCP component **132** and the MCP component **132** has external connections. The flex assembly **130** in its entirety takes the place of a rigid printed circuit board that is traditionally attached beneath the base plate of the drive. All of the typical



modules found in a disc drive control system, such as an interface module, microprocessor, memory, read/write channel, and disc controller are incorporated into these components **132** and **134**.

The power combo chip **134** preferably includes the output circuitry  
5 necessary to control and drive the VCM **124** and the spindle motor **106**. The external connections of the MCP component **132** and the power combo chip **134** are preferably soldered directly onto the flexible circuit **131** of the flex assembly **130**.

The standard external interface connector **150** is fastened to one end of the  
10 base plate **102** for connection of the drive **100** to external components (not shown). The stiffener plate **140** is preferably made of aluminum, as is typically the base plate **102**. The flexible circuit **131** of the flex assembly **130** is preferably bonded to the aluminum stiffener **140**, for example, using an adhesive. In addition to providing stiffness for connecting and disconnecting the connector **150** from the  
15 assembly, the stiffener **140** provides a ground plane **141** for the electronics on the flex assembly **130**. In addition, the stiffener **140** incorporates an insulated power plane **142** connecting power to components **132** and chips **134**. Power plane **142** preferably rests on a layer of insulating material, such as Mylar, to insulate the power plane **142** from the ground plane **141** of the aluminum stiffener **140**. The  
20 power plane **142** may alternatively simply be routed out of the stiffener **140** to separate it from the ground plane **141**. Power plane **142** and ground plane **141** would then simply be insulated from each other by a horizontal gap between them formed by the routing operation. The ground plane **141** and power plane **142** would then be adhesively bonded to the flexible circuit **131** and the components  
25 **132**, **133** and **134** staked to the power plane and ground plane **142** and **140** via pins on the components and pads on the flexible printed circuit **131**.

Figure **3** is a plan view of the flex printed circuit assembly **130** connected to the connector **150**. The flexible circuit **131** has a generally rectangular portion and an elongated connector portion along one edge inserted within the connector **150**,  
30 coextensive with the stiffener plate **140**. The flexible circuit **131** has pigtail leads **162** and **164** extending from edges of the rectangular portion spaced from the connector portion. These pigtail leads **162** extend beneath the cover **104** of the disc

drive 100 as shown in FIG. 1. Pigtail lead 162 preferably carries, at its free end, a preamplifier 165. This preamplifier 165 is mounted on the side of the actuator assembly 110, as close as possible to the heads 118 on the actuator assembly 110 and is used to amplify the small read signals from the heads 118. An alternate  
5 location for the preamplifier 165, not shown, may be on the flex circuit adjacent the components 132 and 134, although, with the small signal strengths of signals from magnetoresistive read elements on the heads 118, a remote mounting of the preamplifier 165 is preferred. Pigtail lead 162 forms a curved flexible service loop type connection between the electronics on the flexible circuit 131 and the actuator  
10 assembly 110 so as to minimize any torque on the actuator arms in a conventional manner. Pigtail lead 164 extends from the edge of the rectangular portion of the flexible circuit 131 and lies essentially flat and extends straight under the discs 108 to the spindle motor 106. Pads on the lead 162 contact a connector on the bottom of the motor 106 to provide the requisite electrical connections to the motor 106.

15 The flex assembly 130 is preferably fastened to the base plate 102. The attachment to the base plate 102 can be achieved by a variety of methods. For example, the flex assembly 130 can be screwed or staked onto the base plate 102 or it could be attached using a pressure-sensitive adhesive. The flex assembly 130 is preferably installed on the base plate 102 prior to placement of the HDA  
20 components on the base plate 102. Assembly of the flex assembly 130 and connector 150 to the base plate 102 does not need to take place in a controlled clean room. Once the flex assembly 130 is attached to the base plate 102, the unit can then be placed in a clean environment, and the actuator assembly 110, discs 108 and spindle motor 106 installed. Then the lead 162 of the flex assembly 130  
25 can be attached to the actuator assembly 110, and the head wires connected to the preamplifier 165 the respectively.

Alternatively, the leads 162, 164 of the flex assembly 130 could be soldered to the actuator assembly 110 and spindle motor 106 prior to attachment of the flex assembly 130 to the base plate 102. The manner in which the leads 162, 164  
30 connect to the actuator assembly 110 and spindle motor 106 is generally known and further description is not necessary. Pigtail lead 162 can be formed into a



service loop and alternatively attached to an aluminum L-bracket either separately fastened to the base plate **102** or integrated into the stiffener **140**.

Once the leads **162**, **164** are connected to the actuator assembly **110** and spindle motor **106**, the top cover **104** is installed onto the base plate **102**. This attachment is generally achieved by screwing the top cover **104** onto the base plate **102**. A flexible seal is placed around the perimeter of the top cover **104** between the cover **104** and the base plate **102** in order to ensure that the environment between the top cover **104** and the base plate **102** remains clean and uncontaminated. This seal is preferably located under the peripheral edge of the cover **104** so that the cover **104** is pressed uniformly against the base **102**, against and over the leads **162**, **164** to maintain the HDA free of contaminants when the cover **104** is securely fastened to the base plate **102** via screws or other fasteners.

As shown in Figures **1** and **4**, the top cover **104** is shaped so that it covers all the major moving components of the disc drive, such as the actuator assembly, disc, and spindle motor, and yet clears the rectangular portion of the flex assembly **130** supporting the electronic control and power components **132** and **132**. Preferably, the top cover **104** only covers the leads **162** and **164** of the flex assembly **130**. Although not shown in the exemplary embodiments illustrated, the cover **104** may extend to and cover portions of the connector **150**.

The top cover **104** is preferably shaped in this manner for several reasons. Because the flex assembly **130** is located outside the top cover **104**, the flex assembly **130** does not have to be manufactured and/or assembled in a clean room environment. Therefore, manufacturing costs can be decreased. Also, because the MCP **132** and power combo chip **134** are outside of the covered HDA, those electrical components remain available for further final testing after the top cover **104** is assembled onto the base plate **102**. In addition, these components receive convection cooling from surrounding airflow.

By providing MCP component **132** and power combo chip **134** on top of the flex assembly **130**, physical electrical connections are minimized and traditional connectors can be eliminated. For example, the disc drive **100** no longer requires a pass-through connector to conduct power and signals between the printed circuit board on the underside of the disc drive to elements of the disc drive

that are mounted on the topside of the base plate. The overall footprint and form factor of the drive can be reduced. The bottom of the disc drive **100** may be flat, and eliminating any need for spacing from adjacent structures and may facilitate denser packaging of multiple disc drives together.

5           An alternative embodiment of a flex assembly **230** is shown in FIGS. **5**, **6**, and **7**. In this embodiment, the principal difference from assembly **130** is in the arrangement of the pigtail lead **266** that is electrically connected to the actuator assembly **110**. In this alternative embodiment **230**, the description set forth above regarding the structure of the stiffener **140**, the ground plane **141** and power plane  
10   **142**, the staking interconnection of the planes with the flexible circuit components **132**, **133** and **134**, and connector **150** is the same and therefore will not be repeated here. The pigtail lead **264** which leads to the spindle motor **106** also remains the same as in the first embodiment **130**. The pigtail lead **266**, for the actuator assembly **110**, in this alternative, is different.

15           In this alternative embodiment, a separate pigtail lead **268**, with a preamplifier **265** attached, is preferably separately assembled to the actuator assembly **110** prior to assembly of the head disc assembly onto the base plate **102**. The flex assembly **230** in accordance with this embodiment, is manufactured with one lead **264** and one short pigtail lead **266** that includes a solder pad as is shown  
20   in FIG. **6**. It may be desired to have the pigtail lead **268** connected to the actuator assembly **110** during the manufacturing process of the actuator assembly **110**, perhaps at a separate vendor, to simplify the final assembly of the disc drive **100**. In this embodiment as in the first embodiment, the flex assembly **230**, with connector **150** attached, is fastened to the base plate **102**. Then the base plate **102**  
25   may be placed in a clean environment and the HDA components installed. The lead **268** can then simply be soldered directly onto pad **266**. Finally, the cover **104** is installed as has been previously described.

          As another alternative, the short lead **266** may, in fact, be shortened so as to be outside the cover **104** when the cover **104** is installed. In this alternative, the  
30   pigtail **268** would extend beneath the installed cover **104** during the assembly process and the assembled drive removed from the clean environment for soldering of the pigtail lead **268** to the pads on the short lead **266**. Again, in this

embodiment, the preamplifier **265** may be located on the pigtail lead **268**, or alternatively, if signal conditions permit in the design, preamplifier **265** could be located on the rectangular portion of the flexible circuit **230** adjacent the components **132** and **134**.

5           It will be clear that embodiments of the present invention are well adapted to attain the ends and advantages mentioned as well as those inherent therein. While presently preferred embodiments have been described for purposes of this disclosure, various changes and modifications may be made which are well within the scope of the present invention. For example, the shape and orientation of the  
10   flex printed circuit assemblies **130** and **230** and top cover **104** can be changed without departing from the scope of the present invention. The cover **104** may cover portions or all of the flexible circuit assembly **130** in alternative designs. The stiffener **140**, ground plane **142** and power plane **141** may be shaped differently than as described and shown. In addition, the flex circuit assembly of  
15   the present invention with a ground and power plane integrated into a stiffener plate may be utilized in other environments than in a disc drive as above described. Such a flexible circuit assembly as **130** could be utilized in a variety of hand held electronic devices and any electronics assembly that requires the use of a printed circuit board, in place of the printed circuit board. Numerous other changes may  
20   be made which will readily suggest themselves to those skilled in the art and which are encompassed in the spirit of the invention disclosed and as defined in the appended claims.